

**Problem 1.15**

[Difficulty: 5]

**1.15** For Problem 1.14, the initial horizontal speed of the sky diver is 70 m/s. As she falls, the  $k$  value for the vertical drag remains as before, but the value for horizontal motion is  $k = 0.05 \text{ N} \cdot \text{s/m}^2$ . Compute and plot the 2D trajectory of the sky diver.

**Given:** Data on sky diver:  $M = 70 \text{ kg}$   $k_{\text{vert}} = 0.25 \frac{\text{N} \cdot \text{s}^2}{\text{m}^2}$   $k_{\text{horiz}} = 0.05 \frac{\text{N} \cdot \text{s}^2}{\text{m}^2}$   $U_0 = 70 \frac{\text{m}}{\text{s}}$

**Find:** Plot of trajectory.

**Solution:** Use given data; integrate equation of motion by separating variables.

Treat the sky diver as a system; apply Newton's 2nd law in horizontal and vertical directions:

Vertical: Newton's 2nd law for the sky diver (mass  $M$ ) is (ignoring buoyancy effects):  $M \frac{dV}{dt} = M \cdot g - k_{\text{vert}} V^2$  (1)

For  $V(t)$  we need to integrate (1) with respect to  $t$ :

Separating variables and integrating:  $\int_0^V \frac{V}{\frac{M \cdot g}{k_{\text{vert}}} - V^2} dV = \int_0^t 1 dt$

so  $1 = \frac{1}{2} \sqrt{\frac{M}{k_{\text{vert}} g}} \ln \left( \frac{\sqrt{\frac{M \cdot g}{k_{\text{vert}}} + V}}{\sqrt{\frac{M \cdot g}{k_{\text{vert}}} - V}} \right)$

Rearranging:  $V(t) = \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \frac{\left( e^{2 \sqrt{\frac{k_{\text{vert}} g}{M}} t} - 1 \right)}{\left( e^{2 \sqrt{\frac{k_{\text{vert}} g}{M}} t} + 1 \right)}$  so  $V(t) = \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \tanh \left( \sqrt{\frac{k_{\text{vert}} g}{M}} t \right)$

For  $y(t)$  we need to integrate again:  $\frac{dy}{dt} = V$  or  $y = \int V dt$

$y(t) = \int_0^t V(t) dt = \int_0^t \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \tanh \left( \sqrt{\frac{k_{\text{vert}} g}{M}} t \right) dt = \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \ln \left( \cosh \left( \sqrt{\frac{k_{\text{vert}} g}{M}} t \right) \right)$

$y(t) = \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \ln \left( \cosh \left( \sqrt{\frac{k_{\text{vert}} g}{M}} t \right) \right)$

# Introduction To Fluid Mechanics 8th Edition Solution Manual

**James G. Speight**



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## **Table of Contents Introduction To Fluid Mechanics 8th Edition Solution Manual**

1. Understanding the eBook Introduction To Fluid Mechanics 8th Edition Solution Manual
  - The Rise of Digital Reading Introduction To Fluid Mechanics 8th Edition Solution Manual
  - Advantages of eBooks Over Traditional Books
2. Identifying Introduction To Fluid Mechanics 8th Edition Solution Manual
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Introduction To Fluid Mechanics 8th Edition Solution Manual
  - User-Friendly Interface
4. Exploring eBook Recommendations from Introduction To Fluid Mechanics 8th Edition Solution Manual
  - Personalized Recommendations
  - Introduction To Fluid Mechanics 8th Edition Solution Manual User Reviews and Ratings
  - Introduction To Fluid Mechanics 8th Edition Solution Manual and Bestseller Lists
5. Accessing Introduction To Fluid Mechanics 8th Edition Solution Manual Free and Paid eBooks
  - Introduction To Fluid Mechanics 8th Edition Solution Manual Public Domain eBooks
  - Introduction To Fluid Mechanics 8th Edition Solution Manual eBook Subscription Services
  - Introduction To Fluid Mechanics 8th Edition Solution Manual Budget-Friendly Options
6. Navigating Introduction To Fluid Mechanics 8th Edition Solution Manual eBook Formats
  - ePub, PDF, MOBI, and More
  - Introduction To Fluid Mechanics 8th Edition Solution Manual Compatibility with Devices
  - Introduction To Fluid Mechanics 8th Edition Solution Manual Enhanced eBook Features
7. Enhancing Your Reading Experience

- Adjustable Fonts and Text Sizes of Introduction To Fluid Mechanics 8th Edition Solution Manual
  - Highlighting and Note-Taking Introduction To Fluid Mechanics 8th Edition Solution Manual
  - Interactive Elements Introduction To Fluid Mechanics 8th Edition Solution Manual
8. Staying Engaged with Introduction To Fluid Mechanics 8th Edition Solution Manual
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Introduction To Fluid Mechanics 8th Edition Solution Manual
  9. Balancing eBooks and Physical Books Introduction To Fluid Mechanics 8th Edition Solution Manual
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Introduction To Fluid Mechanics 8th Edition Solution Manual
  10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
  11. Cultivating a Reading Routine Introduction To Fluid Mechanics 8th Edition Solution Manual
    - Setting Reading Goals Introduction To Fluid Mechanics 8th Edition Solution Manual
    - Carving Out Dedicated Reading Time
  12. Sourcing Reliable Information of Introduction To Fluid Mechanics 8th Edition Solution Manual
    - Fact-Checking eBook Content of Introduction To Fluid Mechanics 8th Edition Solution Manual
    - Distinguishing Credible Sources
  13. Promoting Lifelong Learning
    - Utilizing eBooks for Skill Development
    - Exploring Educational eBooks
  14. Embracing eBook Trends
    - Integration of Multimedia Elements
    - Interactive and Gamified eBooks

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